(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 August 2002 (22.08.2002)

PCT

(10) International Publication Number
WO 02/065564 A2

(51) International Patent Classification[7]: H01M 8/00

(21) International Application Number: PCT/GB02/00678

(22) International Filing Date: 15 February 2002 (15.02.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0103779.5 15 February 2001 (15.02.2001) GB

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(81) Designated States (*national*): AE, AG, AL, AM, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), DE (utility model), DK (utility model), DM, DZ, EC, EE (utility model), ES, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK (utility model), SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent

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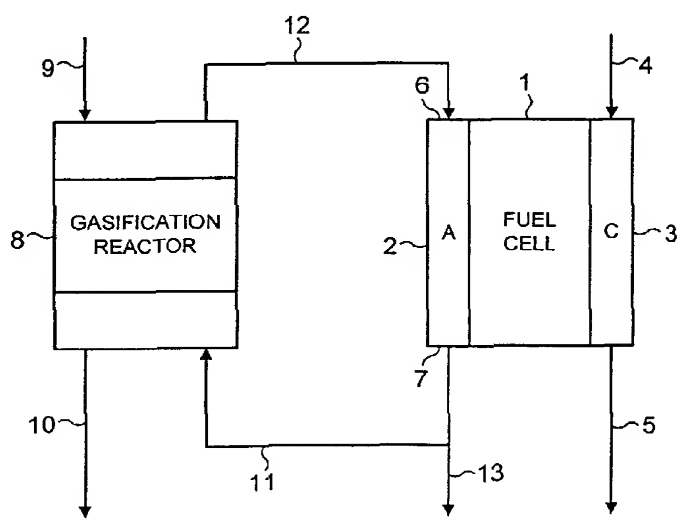
(54) Title: FUEL CELLS



(57) Abstract: A fuel cell system employs a thermally and chemically integrated gasification reactor. The fuel cell (1) converts a part of the gaseous fuel (12) passing through its cell structure to electricity and heat. A part of the depleted fuel (11) is fed into a gasification reactor (8) containing solid carbonaceous material (9). The anode exhaust gas (11) provides the chemical reactants for the gasification process. The anode exhaust gas (11) also provides all or part of the required heat for the endothermic gasification pro cess. The heat from the oxidant gas (5) and the exhaust gas (11) is transferred indirectly to the gasification reactor. The oxidant (5) does not enter the gasification reactor, unless required for heat balancing during operation of the system. A second fuel cell and/or and afterburner may optionally be provided downstream of the first fuel cell.

WO 02/065564 A2

(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

FUEL CELLS

This invention relates to fuel cell systems and particularly, but not exclusively, to those including a gasifier for producing gaseous fuel to supply to the fuel cell.

There is an ever increasing need to produce power as efficiently and cleanly as possible. Of particular concern is the discharge of carbon dioxide into the atmosphere. This is widely recognised to contribute to global warming and thus efforts are made to reduce carbon dioxide emissions into the atmosphere. One way of achieving this is of course to increase the efficiency with which power is generated from fuel.

Gasification of combustible solids is traditionally performed utilising partial oxidation of the solids to generate the required heat for the gasification process. A conventional power generation system consists typically of a coal combustor and a turbine. The most advanced systems today are Integrated Gasification Combined Cycle (IGCC) systems, in which the traditional coal combustor is replaced with a gasifier and gas turbine. Exhaust heat from the gas turbine is used to produce steam for a conventional steam turbine. The gas and steam turbines operate together as a combined cycle. First-generation IGCC power systems capable of achieving efficiencies up to 42 percent are now at the commercial demonstration stage of development and efficiencies up to 50% are expected in the future. These systems are however complex systems consisting of several power generation steps, and can today only be realised in multi-megawatt systems.

Another potential way of reducing carbon dioxide emissions into the atmosphere is to capture and store the carbon dioxide produced by the power generation process. This is problematic in conventional power

generation systems based on combustion in air, however, since the carbon dioxide in the combustion products is mixed with a large amount of nitrogen. The presence of nitrogen makes the capture and separation of carbon dioxide significantly more expensive.

In recent years there has been a lot of interest in fuel cells which are devices which are able to generate an electric current and heat directly from fuel without combustion. The direct generation of electric current means that the efficiency of such devices is not limited by thermodynamic efficiency limits. Furthermore, the products of such fuel cells are mainly water vapour and carbon dioxide, but since no combustion is involved, there is not a large amount of nitrogen present and thus the carbon dioxide may be separated and stored more economically.

Fuel cells operate on gaseous fuel, usually hydrogen (H_2), methane (CH_4) or carbon monoxide. A gasifier is therefore necessary to convert the fuel from the solid carbonaceous form in which it is normally found to the required gaseous form. In practical terms, hydrogen is generally considered to be the best fuel on which to operate fuel cells, not least because it does not give carbon dioxide as a by-product, and thus known systems are set up to maximise the proportion of H_2 generated.

Gasifiers conventionally operate on partial combustion of the fuel and/or require steam to provide heat and water to react with the solid fuel. The disadvantages of combustion are set out above. Furthermore, the necessity to generate steam gives rise to extra apparatus and complexity - hence making such systems relatively expensive.

Some examples of known systems are given hereinbelow. Firstly, US 5955039 describes a system including a fuel cell using a coal gasifier. The system uses partial combustion and steam addition for the coal

gasifier, and a turbine to generate electricity. The partial combustion and steam addition make this relatively inefficient and complex. Furthermore, the use of a turbine increases the complexity, and limits the application to certain size ranges.

US 5554453 discloses a fuel cell system including a gasifier and a catalytic burner. A steam generator is necessary to provide the reactants for gasification. As a result this system is also relatively complex and inefficient.

WO 99/52166 discloses a method of gasifying a carbon-comprising material at elevated temperatures within the structure of a fuel cell. Since this arrangement requires the carbon-comprising material to be in electrical contact with an electrode of the fuel cell in cannot be used in conventional fuel cell systems, such as solid oxide fuel cells.

WO 98/08771 discloses an apparatus and method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide for use in combination with fuel cells. The method is based on partial combustion.

Finally, DE 3913322 discloses a fuel cell with allothermic coal gasification, where the heat required for the gasification process is supplied by a high temperature solid oxide fuel cell (SOFC). The exhaust gas is used as a heat carrier and fluidisation agent. Steam is generated elsewhere to be used as an oxidant for the gasification process.

All these known systems use either partial oxidation or steam generation to supply heat and reactants for the gasification process. As mentioned above, partial oxidation reduces the potential efficiency of the system and makes the recapture of waste carbon dioxide more difficult. The generation of steam requires one or more specific process steps to be included in the system, thereby limiting efficiency and making the overall system complex and thus costly.

It is an object of the present invention to provide an improved arrangement and when viewed from a first aspect the invention provides a power generation system comprising a gasifier module for carrying out a gasification reaction to convert a fuel into gaseous fuel and a fuel cell module, said modules being arranged so that said gasifier module supplies gaseous fuel to the fuel cell module, wherein at least a portion of the exhaust gas from said fuel cell module is recycled back into the gasifier to provide one or more reactants for said gasification reaction.

Similarly, when viewed from a second aspect, the invention provides a method of generating power comprising carrying out a gasification reaction in a gasifier module to convert a fuel into gaseous fuel, supplying said gaseous fuel to a fuel cell module, generating an electric current in said fuel cell module and recycling at least a portion of the exhaust gas from said fuel cell module back into the gasifier to provide one or more reactants for said gasification reaction.

Thus it will be seen that in accordance with the invention the fuel cell exhaust gas is used to provide reactants for the gasification, i.e. the gasifier and fuel cell are chemically integrated. In at least preferred embodiments of the invention this can obviate the need either for partial combustion of the fuel in the gasifier or to add steam. Furthermore it reduces the number of stages in the power generation process and increases it's overall efficiency, thereby reducing its overall cost.

In particular the applicants have realised that if the fuel cell is operated on an increased proportion of carbon monoxide (CO) rather than hydrogen, the otherwise undesirable increase in carbon dioxide in the fuel cell's by-products can be used as the reactant for gasification. It will be appreciated that this is contrary to the understanding that the fuel cell should

be run on a hydrogen-maximised fuel. However, taken as a whole, by recycling the exhaust gases chemically, power generation systems in accordance with the present invention can offer an improvement in efficiency over known systems.

Since carbon dioxide from the fuel cell is used as a gasification reactant and some steam is also present in the fuel cell exhaust stream, no separate steam generation is required to provide steam for the gasification reaction. The apparatus is therefore simpler and less costly. Its overall efficiency is also improved. Furthermore it is not necessary in accordance with preferred embodiments of the invention to provide any additional reactants to the gasifier for the gasification reaction.

Moreover the integration works in the opposite sense as well in that the fuel cell of at least preferred embodiments of the invention is able to use solely the output from the gasifier as its fuel - i.e. without requiring any further inputs apart from an oxidant such as oxygen (O_2). Embodiments of the invention are therefore able to be extremely simple and compact.

When viewed from a further aspect therefore, the present invention provides a method of generating electrical power using a combined gasifier and fuel cell system comprising operating said gasifier predominantly on carbon dioxide and operating said fuel cell predominantly on carbon monoxide.

However, it has further been appreciated that at least some of the benefits of using the exhaust gas from a fuel cell to provide the reactants for a fuel gasifier may be realised even if the fuel is not used or used exclusively to power the fuel cell.

When viewed from a further broad aspect therefore, the present invention provides a fuel cell system comprising a fuel cell having an anode portion and a

cathode portion; and a gasifier for gasification of hydrocarbon, preferably solid, fuels which receives reactants for the gasification from the anode exhaust stream of said fuel cell. In accordance with this aspect of the invention the fuel produced could be used for the fuel cell, or an external process, or part thereof may be used for each purpose.

As well as electricity, the fuel cell will normally also produce heat, a proportion of which is manifested as an elevated exhaust gas temperature. This heat could be removed - e.g. in a heat exchanger - to be used for other purposes. More preferably though, the heat is used to supply at least a portion, and most preferably all, of the heat required for the endothermic gasification reaction. Thus in preferred embodiments the system is arranged so that the exhaust gas carries heat into the gasification reactor. Since the exhaust gas is directly introduced into the gasifier, the heat transfer is optimised. This is to be compared with prior art systems in which heat is transferred indirectly from fuel cell exhaust gas to a gasifier by means of a heat exchanger.

Thus in its preferred embodiments the invention provides a chemically and thermally integrated gasifier and fuel cell system. The improvements in efficiency and reductions in cost which such integration offers makes power generation systems in accordance with the invention significantly advantageous compared to prior art systems. A further synergistic benefit is obtained in that the efficient removal of heat from the fuel cell reduces the need to cool the fuel cell with a high air flow.

In the preferred embodiments of the invention it is the anode exhaust gas which is chemically, and preferably thermally, recycled back to the gasifier. Preferably heat from the cathode exhaust is also recovered.

In some circumstances it may be desirable to pass the cathode exhaust gas directly into the gasifier. Since the cathode gas will comprise an oxidant, this will encourage partial combustion of the fuel to generate heat, carbon dioxide and water as in known gasification systems. This may be desirable e.g. in transient phases of operation such as start up or when changing the output of the system - when extra heat may be required. It will thus be apparent that a combination of combustive and non-combustive gasification is contemplated within the scope of the invention.

Preferably the cathode exhaust heat is recycled indirectly by passing it through a heat exchanger and using a carrier fluid. In some preferred embodiments the gaseous fuel generated in the gasifier is itself used as the carrier fluid by diverting a portion thereof from the output of the gasifier, via such a heat exchanger, back into the gasifier. The advantage of extracting heat from the cathode exhaust gas is that higher gasification rates may be achieved by virtue of the higer temperature of the recycled input gases. This enriches the gaseous fuel input into the fuel cell - e.g. in preferred embodiments it increases the ratio of carbon monoixide to carbon dioxide. The advantage of using the gaseuos fuel itself as the heat carrier is that it reduces the volume flow of the enriched fuel into the fuel cell thereby enhancing fuel utilisation by reducing any tendency to saturation of the fuel cell.

Although systems in accordance with the present invention can be realised without requiring any combustion of the fuel, it may be desirable in some circumstances to burn any unused fuel exiting the fuel cell in an afterburner. Since preferred embodiments of the invention have a high fuel utilisation, only a small amount of air or oxygen is required to burn the fuel completely. This will result in at most a small amount

of nitrogen in the combustion products enabling relatively easy capture of the carbon dioxide generated. The heat generated from this can be used for any external purpose or may be used to supply further heat to the gasifier module. Although an external air or oxygen source could be used to oxidise the combustion on the afterburner, in the preferred of such embodiments, the oxidant used in the fuel cell is used as the oxidant in the afterburner.

Any suitable fuel cell can be used. Preferably a solid oxide or molten carbonate fuel cell is used, with a solid oxide fuel cell being the most preferred.

Similarly there are many suitable types of gasifier such as waste material or biomass gasifiers, but preferably the gasifier module comprises a solid carbonaceous gasifier, most preferably a coal gasifier.

The invention may be successfully applied with a single fuel cell. However it has been found that electrical efficiency, fuel utilisation and overall power density may be increased further if a portion of the exhaust gas from a fuel cell is used to feed a second fuel cell. Some preferred embodiments of the invention thus have two or more fuel cells in series.

The beneficial effects have been seen to be particularly beneficial when used in conjunction with gasification in accordance with the invention. It will be appreciated by those skilled in the art that this is contrary to the accepted understanding that whilst serial flow fuel cells, operating at successively lower voltages, will increase the electrical efficiency, the overall power density, and thereby cost per kW of power generated, will be reduced.

Certain preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 shows schematically an embodiment of a fuel cell system including a thermally and chemically

integrated gasifier in accordance with the principles of the present invention;

Fig. 2 shows a second embodiment of the present invention, including, in addition to the system shown in Fig 1, a second fuel cell;

Fig. 3 shows a third embodiment of a fuel cell system in accordance with the invention including, in addition to the gas loop shown in Fig.1, a further heat recycling loop;

Fig. 4 shows a fourth embodiment of the present invention, including an after-burner and an additional heat exchanger;

Fig. 5 shows a fifth embodiment of the present invention, including an after-burner and an additional heat exchanger integrated in the gasification reactor;

Fig. 6 shows a sixth embodiment of the invention identical to the fifth except that a portion of the gaseous fuel produced is branched off for an external process; and

Fig. 7 shows a seventh embodiment of the present invention, including, in addition to the system shown in Fig 5, a heat flow entering the system from an external process.

Turning firstly to Fig. 1, there may be seen a schematic representation of fuel cell system including a thermally and chemically integrated gasifier in accordance with a first embodiment of the present invention.

The fuel cell system generally comprises a gasifier module 100 and a fuel cell module 200. The gasifier module 100 comprises a gasification reactor 8 which has a raw carbonaceous fuel inlet 9, an ash outlet 9, a recycled gas input 11 and a gaseous fuel output 12.

The fuel cell module 200 comprises a high temperature solid oxide fuel cell 1 which includes an anode portion 2 and a cathode portion 3. Between the anode 2 and cathode 3 is a solid electrolyte of yttria

doped zirconia. The solid electrolyte has an anode layer consisting of nickel/zirkonia cermet, which is nickel particles (the catalyst and electron conductor) and particles of yttria doped zirconia (ion conductor); and a cathode layer of strontium doped lanthanum manganite (catalyst and mixed ion/electron conductor). The oxygen reacts at the cathode to oxygen ions.

An inlet 4 to the cathode side 3 of the fuel cell is provides oxygen from an external source (not shown). There is a corresponding outlet 5 for the oxygen at the other end of the cathode side.

On the anode side 2, the gaseous fuel output 12 enters the fuel cell 1 at an inlet 6 and the exhaust gas exits at the other end from an outlet 7. The flow of exhaust gas is divided - a portion thereof is directed back in to the gasifier 8 by means of an inlet pipe 11 and the remainder is ejected from the system as exhaust gas 13. This may however be passed into a carbon dioxide sequestration module (not shown) in order to capture the carbon dioxide therein.

In operation solid carbonaceous material enters the gasification reactor 8 by means of the fuel inlet 9. In the reactor, carbon reacts with the carbon dioxide and water which enter the reactor from the gas recycling input 11, to form carbon monoxide and molecular hydrogen (H_2). There may be also be some organic matter which reacts to give hydrogen and carbon monoxide.

The carbon monoxide and hydrogen are fed by means of the pipe 6 into the anode side 2 of the fuel cell. At the same time oxygen 4 is fed into the cathode side. As is known to those skilled in the art, the oxygen ions pass through the solid electrolyte and react at the anode side with carbon monoxide / hydrogen, producing carbon dioxide and steam respectively and freeing electrons and generating heat. The carbon dioxide and steam are recycled back into the gasifier 8, by means of the fuel cell outlet 7 and the gasifier inlet 11, in

order to provide the required reactants for the gasification reaction, as mentioned above. The oxygen passes out of the fuel cell via the outlet pipe 5.

As well as providing the chemical reactants for the gasification reaction, the recycled exhaust gases 11 carry the heat generated in the fuel cell 1 into the gasification reactor 8. This provides the necessary heat for the gasification reaction to take place and also provides a degree of cooling for the fuel cell. The high grade of heat in the exhaust gas can also be used in thermodynamic cycles to increase the electrical efficiency further.

It will be appreciated from the foregoing that the gas in branch 12 will have a higher content of carbon monoxide and hydrogen and a lower temperature than the gas in branch 11.

The anode gases exiting the outlet 7 will typically also contain some unoxidised fuel. The unoxidised fuel content of the gases which are passed into the system exhaust 13 is low and thus they can be burned completely with only a small amount of air or oxygen, meaning the ultimate exhaust gas will contain little or no nitrogen, allowing easy capture of carbon dioxide.

Example 1

A system corresponding to that shown schematically in Fig 1 was operated on solid carbon as the raw fuel, at a reactor temperature of between 800 and 1000°C giving the results shown below:

Table 1

CO/CO_2 ratio at anode inlet 6	0.25
CO/CO_2 ratio at anode outlet 7	0.1
Cell voltage	0.7V

Ratio no. of moles in branch 11/ no. of moles in branch 13	18
Fuel utilisation	0.95
Electrical efficiency of fuel cell	65%
Electrical efficiency of system	55%

With a CO/CO_2 ratio of 0.25 as shown in the table above, a current density of 250 mA/cm^2 was obtained. This is high enough to be commercially viable.

A second embodiment of the invention is shown schematically in Fig 2. This embodiment is substantially similar to that shown in Fig. 1 and therefore no further explanation of the common elements thereof (denoted by identical reference numerals) will be given. This embodiment differs from the first in that the portion of the anode exhaust gas 13 which is not recycled back to the gasifier 8 is fed, via an inlet 6a, into a second high temperature solid oxide fuel cell 1a, identical in construction to the first fuel cell 1.

More oxidant air enters the fuel cell cathode compartment 3a of the second fuel cell from an air inlet 4a and leaves through an air outlet 5a.

As the ratio of carbon monoxide to carbon dioxide at the outlet of fuel cell 1 is rather high, this fuel cell 1 can be run on a high cell voltage, thus increasing the efficiency of the system. Most of the anode exhaust gas is continuously upgraded in the gasifier, hence the first fuel cell 1 always operates on high grade gas. The increased efficiency can therefore be obtained without reduced power density, as is the case if the stacks were coupled in series with a high cell voltage in the first and successively lower cell voltages from stack to stack, as is known in the art. The excess anode exhaust gas 13 is passed to the second fuel cell 13a operating at a lower cell voltage and where most of the remaining fuel is used.

Example 2

A system corresponding to that shown schematically in Fig 2 was also operated on solid carbon as the raw fuel, at a gasification reactor temperature of between 800 and 1000°C giving the results shown below:

Table 2

CO/CO_2 ratio at anode inlet	1.45
CO/CO_2 ratio at anode outlet 7	1.0
Cell voltage of first cell 1	0.85V
CO/CO_2 ratio at anode inlet 6a	1.0
CO/CO_2 ratio at anode outlet 7a	0.11
Cell voltage of second cell 1a	0.7V
Ratio no. of moles in branch 11/ no. of moles in branch 13	15
Fuel utilisation total	95%
Electrical efficiency of fuel cell 1 and 1a	76%
Electrical efficiency of system	66%

A third embodiment of a fuel cell system including a thermally and chemically integrated gasifier in accordance with the principles of the present invention is shown in Fig. 3. This embodiment is similar to that shown in Fig.1 except that it includes a heat exchanger 14 through which the used oxidant air 5 from the fuel cell 1 passes. The other half of the heat exchanger 14 is in the path of an additional loop 15a, 15b which is arranged to circulate a portion of the gaseous fuel 12 output from the gasifier module 100 back into the input 11 thereof.

In use, the used oxidant air 5 will be at an elevated temperature by virtue of the heat generated in the fuel cell 1. This heat is passed by virtue of the heat exchanger 14 into a portion of gaseous fuel 12

exiting the gasification reactor 8 diverted by means of a pipe 15a. A return pipe 15b returns the heated gaseous fuel to the gasification reactor 8. Although the gas does not undergo any further chemical reactions, it acts as a medium to transfer additional heat to the gasification reactor, thus ensuring that an even greater proportion of the heat generated in the fuel cell 1 is utilised. This gives a higher gasification rate in the gasifier leading to a higer ratio of carbon monoxide to carbon dioxide in the fuel generated and consequently higher power density in the fuel cell 1. The reduced volume flow of gaseous fuel 12 into the fuel cell 1 is beneficial in enhancing fuel utilisation.

Fig. 4 shows schematically a further embodiment of the invention which is a modified version of that shown in Fig. 3. The modification comprises the addition of an afterburner 17 and associated second heat-exchanger 16.

In use the exhaust gas 13 from the anode side 2 of the fuel cell 1 is fed into the afterburner 17 where the remaining fuel therein is burnt in the presence of the oxidant air 5 exiting the cathode side 3 of the fuel cell. The additional heat generated is transferred, by means of the second heat-exchanger 17, to the recycled gaseous fuel 15b exiting the first heat-exchanger 14. It will be noticed however that since the second heat exchanger 17 is located in the flow circuit after the recycled exhaust gases 11 exiting the fuel cell anode side 7 are mixed with the recycled gaseous fuel 15b, both of these are heated prior to being returned by a pipe 15c to the gasification reactor 8.

This arrangement further enhances the amount of energy which is extracted from the fuel and thus increases the overall efficiency of the system.

A further embodiment is shown schematically in Fig. 5. This arrangement is similar to that of the embodiment of Fig. 1. Additionally however, there is provided an afterburner 17 and associated heat exchanger

18, as in the embodiment of Fig. 4. However rather than using either diverted gaseous fuel or exhaust gases as a heat carrier medium, the heat exchanger 18 is integrated into the reaction vessel. This enables the heat generated in the afterburner 17 and carried by its exhaust gases 19 to the heat exhanger 18, to be transferred directly into the gasification reactor 8, thereby minimising potential transmission heat losses.

After exiting the heat exchanger 18, the exhaust gases 20 originally from the afterburner 17 may simply be exhausted into the atmosphere.

Fig. 6 shows schematically an embodiment identical to that of Fig. 5 except that a portion 12a of the gaseous fuel produced in the gasifier 8 is diverted for use in an external process e.g. providing synthesis gas for a chemical plant.

Finally, Fig. 7 shows a modified version of the embodiment of Fig. 5. The only difference is that a second integrated heat exchanger 21 is provided in the gasification reactor 8. The second heat exchanger 21 transfers heat into the gasification reactor from a fluid 22 entering from an external process. The cooled fluid 23 is then returned to the external process. It will be apparent that this arrangement further enhances the efficiency of the power generation system since it can operate at a higher temperature.

It will be seen from the above description that, at least in its preferred embodiments, the present invention is able to provide a method and system for high efficiency energy production by the use of a fuel cell system in combination with gasification of solid carbonaceous material.

The embodiments can further provide a method and system for high efficiency energy production which facilitates the capture of carbon dioxide from the system.

They can further provide a fuel cell system with

gasifier in which the anode exhaust gas from the fuel cell provides heat and the required reactants for the gasification reaction by directly introducing the anode exhaust gas into the gasifier, thus eliminating the need for additional process steps to generate steam or other reactants and transfer heat directly to the gasifier without a heat-exchanger or other indirect means.

The embodiments can yet further provide a fuel cell system with gasifier in which additional heat, when required, is transferred indirectly to the gasifier from the fuel cell and the afterburner using the cathode exhaust gas as a heat carrier.

It will also be seen that they provide a fuel cell system with a gasifier in which the fuel cell can operate effectively on the gas produced in the gasifier without additional process steps, and in which the gasifier can operate effectively utilising the anode exhaust gas in the gasification process.

It will be appreciated by those skilled in the art that there are many potential variations on the embodiments described within the principles of the present invention.

Claims:

1. A power generation system comprising a gasifier module for carrying out a gasification reaction to convert a fuel into gaseous fuel and a fuel cell module, said modules being arranged so that said gasifier module supplies gaseous fuel to the fuel cell module, wherein at least a portion of the exhaust gas from said fuel cell module is recycled back into the gasifier to provide one or more reactants for said gasification reaction.

2. A system as claimed in claim 1 wherein said gasifier receives all or a substantial part of the required reactants for the gasification from said fuel cell.

3. A system as claimed in claim 1 or 2 arranged such that said recycled exhaust gas also acts to carry heat into said gasifier module.

4. A system as claimed in claim 1, 2 or 3 wherein said exhaust gas is from the anode portion of the fuel cell.

5. A system as claimed in claim 4 comprising means to recover heat from exhaust gas from the cathode portion of the fuel cell

6. A system as claimed in claim 5 comprising a heat exchanger through which said cathode exhaust gas is arranged to flow.

7. A system as claimed in claim 6 wherein a portion of the gaseous fuel output from the gasifier module is arranged to enter said heat exchanger such that heat is transferred from the fuel cell cathode exhaust to the gaseous fuel.

8. A system as claimed in any preceding claim comprising a second fuel cell module which is supplied with at least a portion of the exhaust gas from the first fuel cell module which is not recycled back to the gasifier module.

9. A system as claimed in any preceding claim comprising an afterburner downstream of said fuel cell module or modules for combusting any fuel remaining in the exhaust gas therefrom which is not recycled.

10. A system as claimed in any preceding claim wherein said gasifier is a coal gasifier, a biomass gasifier or gasifier for waste material.

11. A system as claimed in any preceding claim wherein said fuel cell is a solid oxide fuel cell or a molten carbonate fuel cell.

12. A fuel cell system comprising a fuel cell having an anode portion and a cathode portion; and a gasifier for gasification of solid hydrocarbon fuels which receives reactants for the gasification from the anode exhaust stream of said fuel cell.

13. A system as claimed in claim 12 wherein all or a part of the output gas from said gasifier is used as a fuel for the fuel cell.

14. A fuel cell system as claimed in claim 13 or 14, wherein:
all or a part of the output gas from said gasifier is used outside the said fuel cell system

15. A method of generating power comprising carrying out a gasification reaction in a gasifier module to convert a fuel into gaseous fuel, supplying said gaseous

fuel to a fuel cell module, generating an electric current in said fuel cell module and recycling at least a portion of the exhaust gas from said fuel cell module back into the gasifier to provide one or more reactants for said gasification reaction.

16. A method of generating electrical power using a combined gasifier and fuel cell system comprising operating said gasifier predominantly on carbon dioxide and operating said fuel cell predominantly on carbon monoxide.

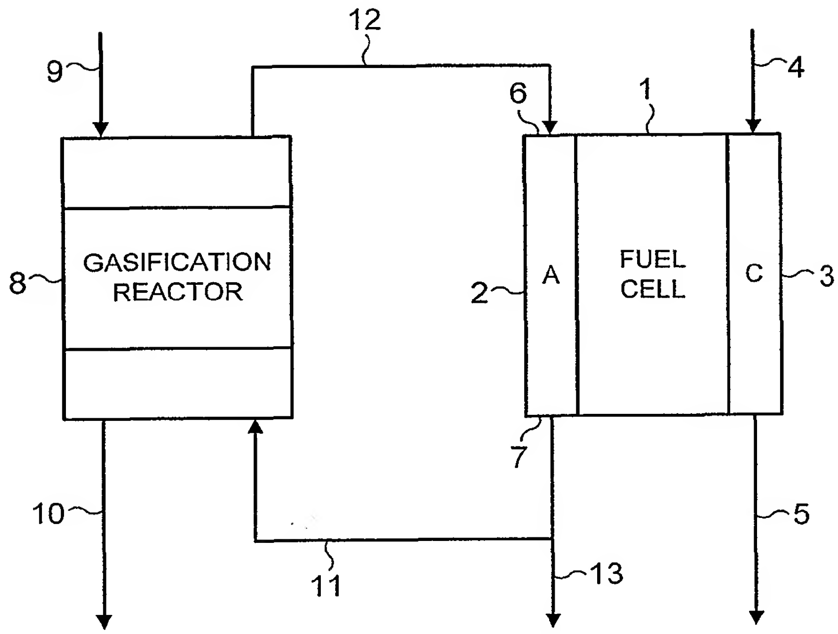


FIG. 1

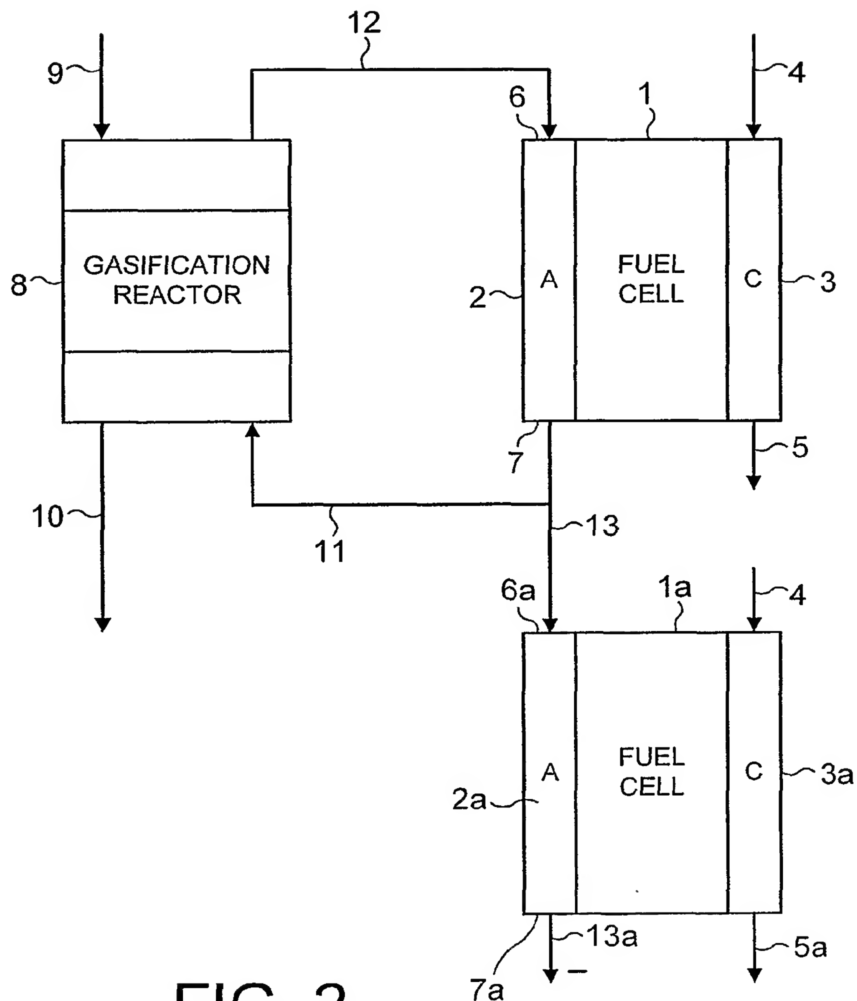

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FIG. 2

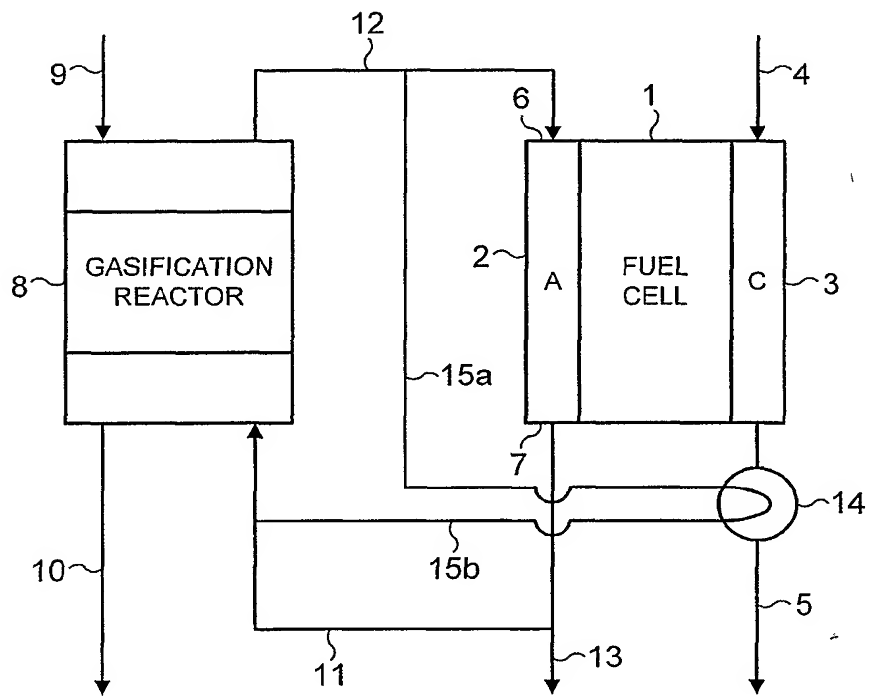
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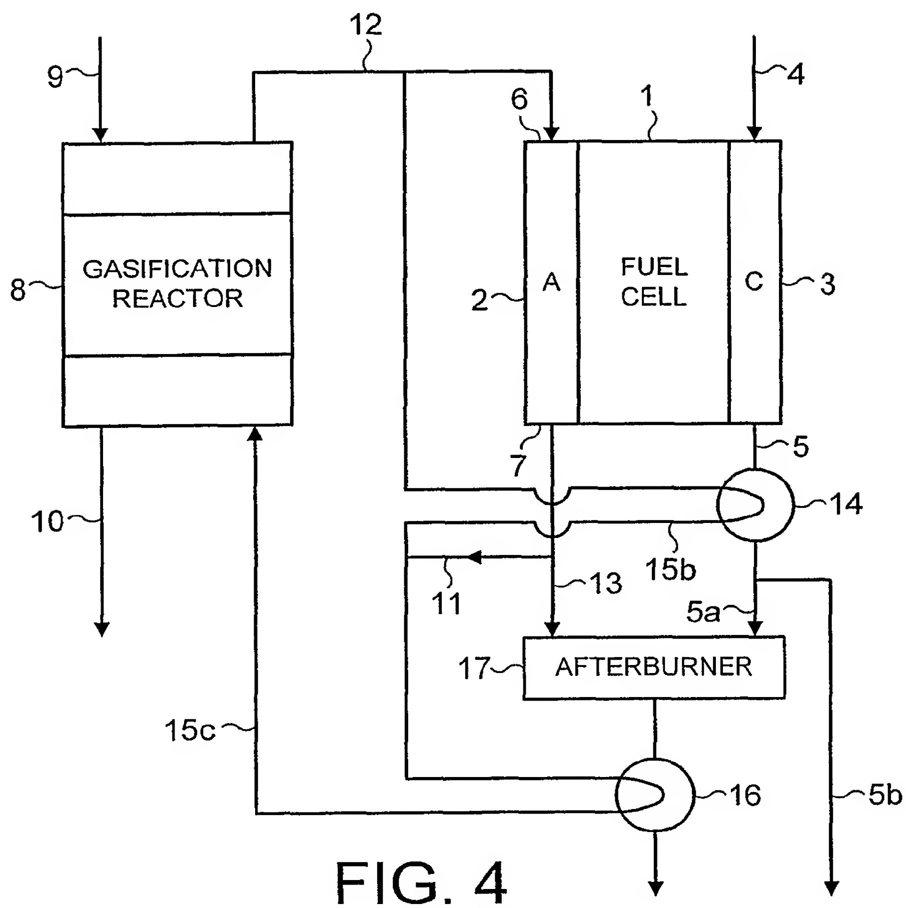
FIG. 3



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FUEL
CELL
C
3
7
5
14
10
15b
11
13
5a
17
AFTERBURNER
15c
16
5b

FIG. 4

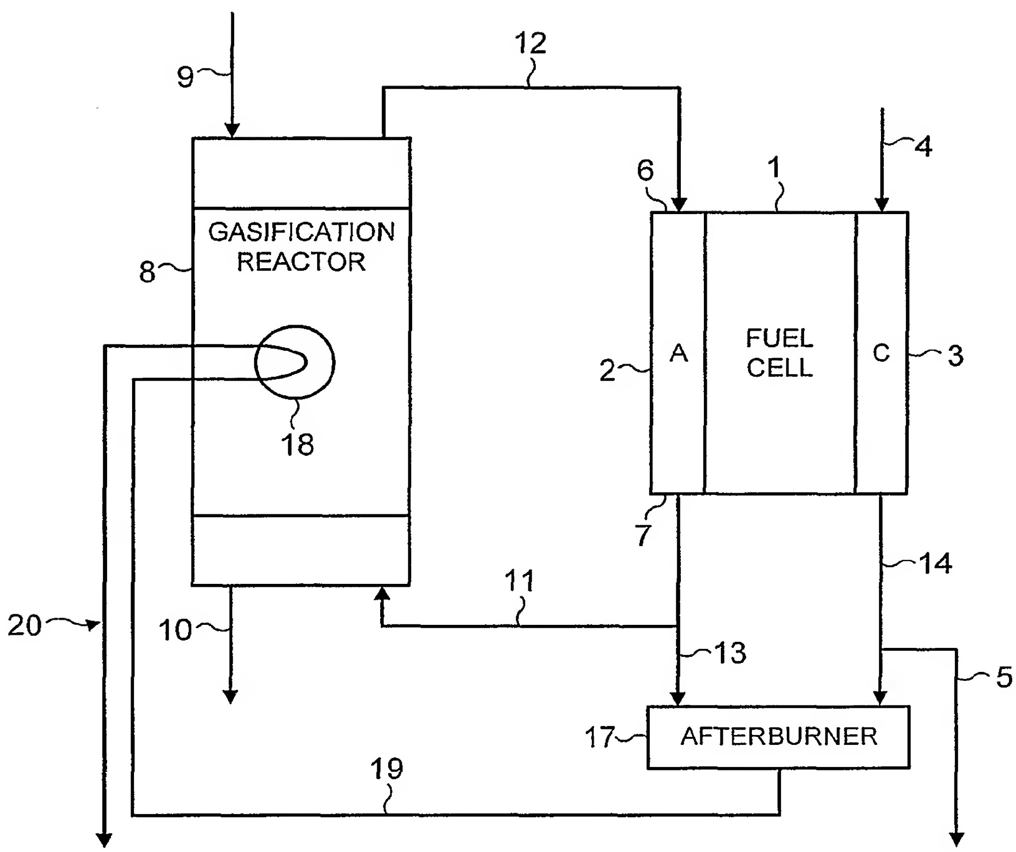
12
9
4
6
1
GASIFICATION REACTOR
8
FUEL CELL
A
C
2
3
18
7
14
11
20
10
13
5
17
AFTERBURNER
19

FIG. 5

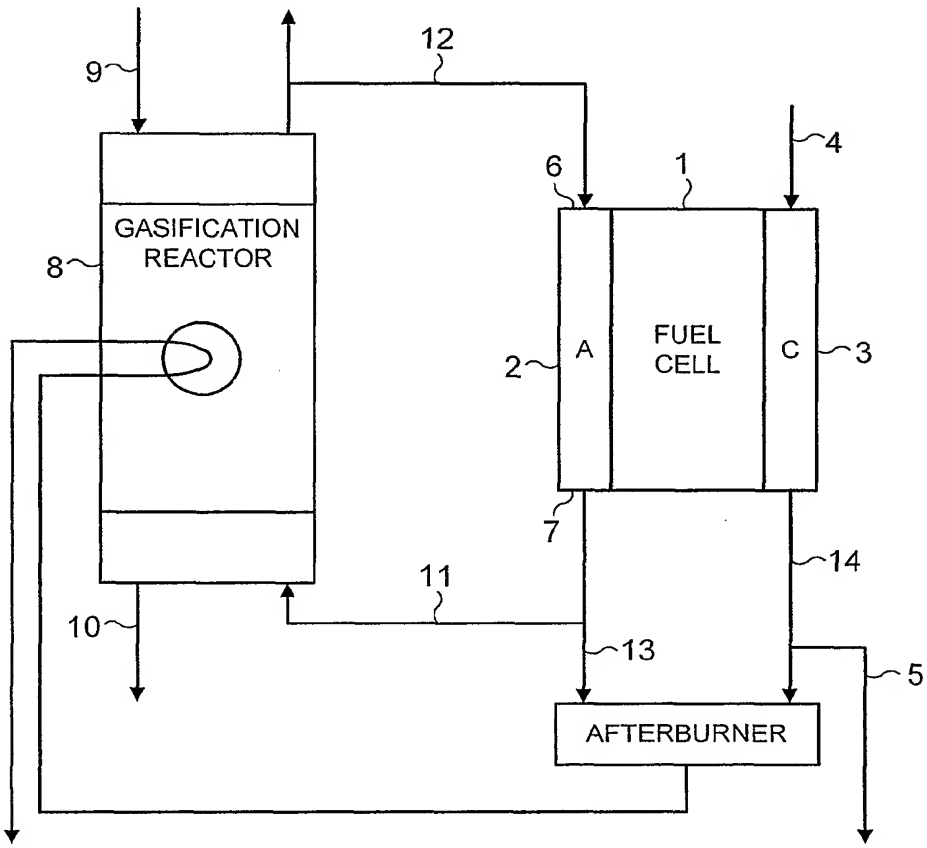
12
9
4
6
1
GASIFICATION
REACTOR
8
A
FUEL
CELL
C
2
3
7
14
11
10
13
5
AFTERBURNER

FIG. 6

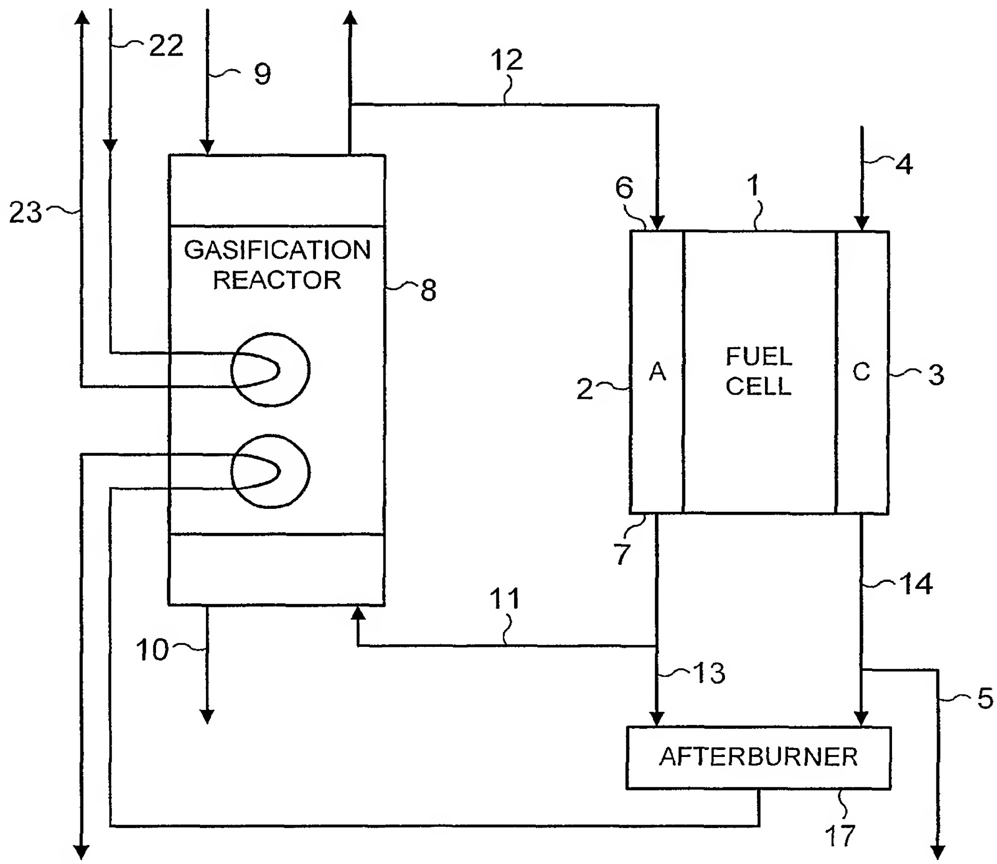
22
9
12
4
23
6
1
GASIFICATION
REACTOR
8
2
A
FUEL
CELL
C
3
7
14
11
10
13
5
AFTERBURNER
17

FIG. 7